

Accelerator Division



P.Illinski
Synchrotron Radiation Protection
NSLS-II ASAC Review
October 14-15, 2010

Synchrotron Radiation Protection Task Force

NSLS-II Synchrotron Radiation Protection Task Force was initiated by ASD Division Director F. Willeke on 07/26/2010

A task force is herewith initiated to assure an overall integrated design of Synchrotron Radiation Protection

Stakeholders

ASD Management, Ferdinand Willeke, Erik Johnson

ASD Accelerator Physics Group, Samuel Krinsky

ASD Instrumentation Group, Om Singh

ASD Safety Systems Group, Erik Johnson

ASD Vacuum Group, Dick Hseuh

ASD Mechanical Engineering Group, Sushil Sharma

Task Force Members

Task Force Leader: Petr Ilinski

The following scientists and engineers are standing members:

Scott Buda, ASD Electrical Engineering Group

Jinhyuk Choi, ASD Acc. Phys. Group

Marcelo Ferreira, ASD Vacuum Group

Igor Pinayev, ASD Acc. Phys., Group

Viswanath Ravindranath, ASD Mechanical Engineering Group

Yong Hu, Controls Group

Oleg Tchoubar, XFD

SRP TF Goals and Deliveries

Charge for SRP TF:

- Define the limits for the beam positions and angles which protect the accelerator components from destructive synchrotron radiation and which leaves sufficient room for residual beam motion to assure stable and reliable operations
- Define the detection system which measures the beam position and angle
- Define the requirements for the equipment protection interlock system which will assure that the high intensity ID radiation will not damage vacuum system components
- Assure that when the electron beam orbit moves outside the allowed range, the interlock system will kill the beam within a short enough time interval to prevent damage
- Define a procedure for checking that vacuum system hardware is properly positioned
- Define a procedure based on observation of the ID radiation at low electron current to calibrate the BPM offsets relative to the position of the vacuum system hardware
- Define a procedure for testing that the interlock system is engaged and properly functioning
- Define interfaces between the equipment protection system and the personal protection system
- Write a report with the specific requirement on the equipment protection system
- Draft any PCR to cover additional cost of analysis, prototyping and final system cost

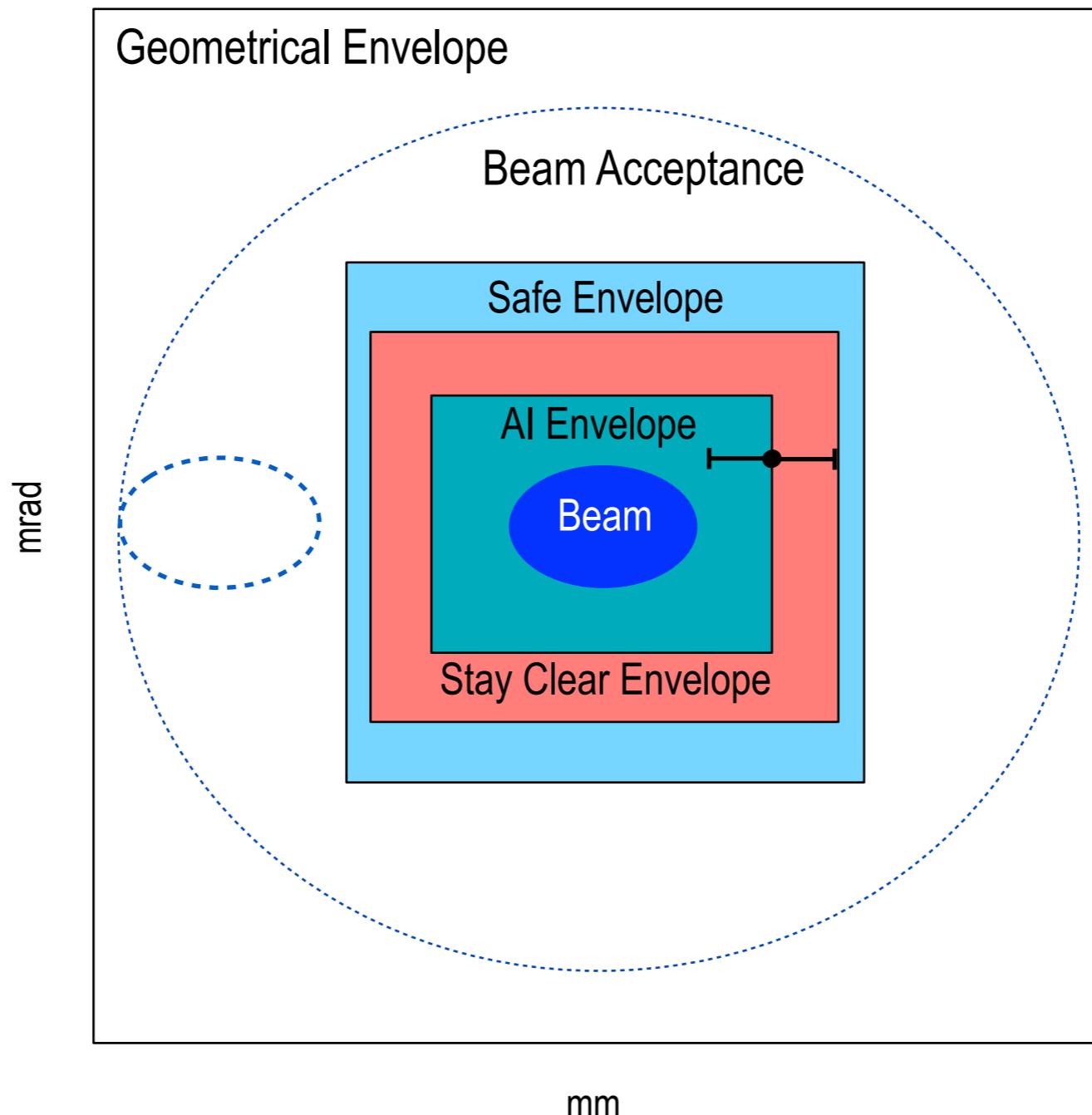
SRP Oversight

- **Passive protection from Dipole Radiation**
 - Full passive protection
- **Envelopes for particular cases**
 - Damping Wiggler
 - IVUs
 - EPUs
 - Dipole (25, 100, 500 mA)
- **Transient Analysis**
 - Maximum safe operation current
 - Maximum beam dumping time
- **Active Interlock**
 - Envelope
 - Specifications
 - Architecture
 - Operation

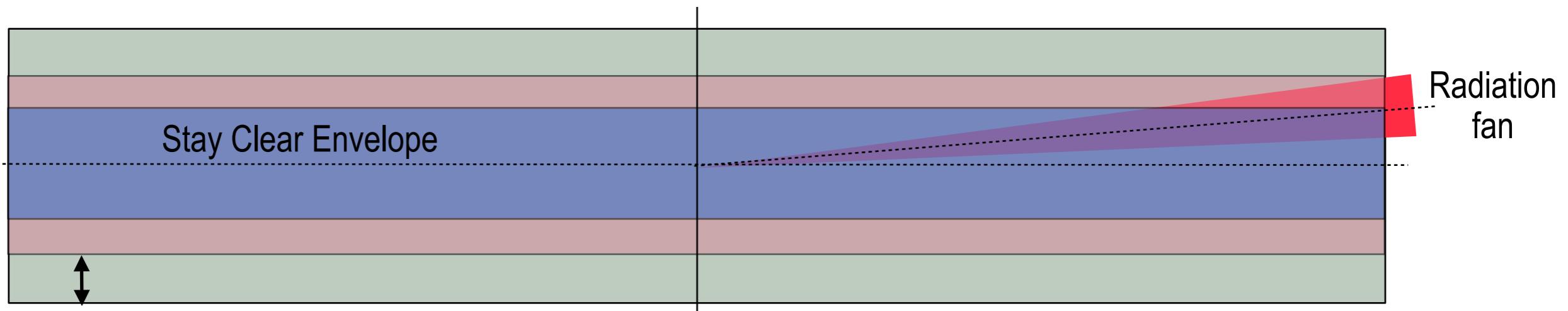
Envelopes

- **Stay Clear Envelope**
 - defines e-beam phase space for Stay Clear Operation
 - radiation fan does not hit machine elements even in case of misalignment
- **Safe Envelope**
 - defines e-beam phase space for Safe Operation
 - Safe Operation satisfies Steady State operation conditions
 - less than 100C for aluminum vacuum chamber
- **Active Interlock Envelope**
 - AI Envelope = Safe/StayClear Envelope - Total uncertainty
 - Total uncertainty = BPM alignment, drifts etc
 - beam will be dumped once it is outside the AI Envelope
- **Geometrical Envelope**
 - Geometrical Envelope is defined by boundaries of the vacuum chamber
- **Beam Acceptance**
 - phase space of maximum beam acceptance of close orbit
 - provides initial conditions for the Transient analysis
 - estimation of maximal time to dump the beam
 - estimation of maximal safe operation beam current

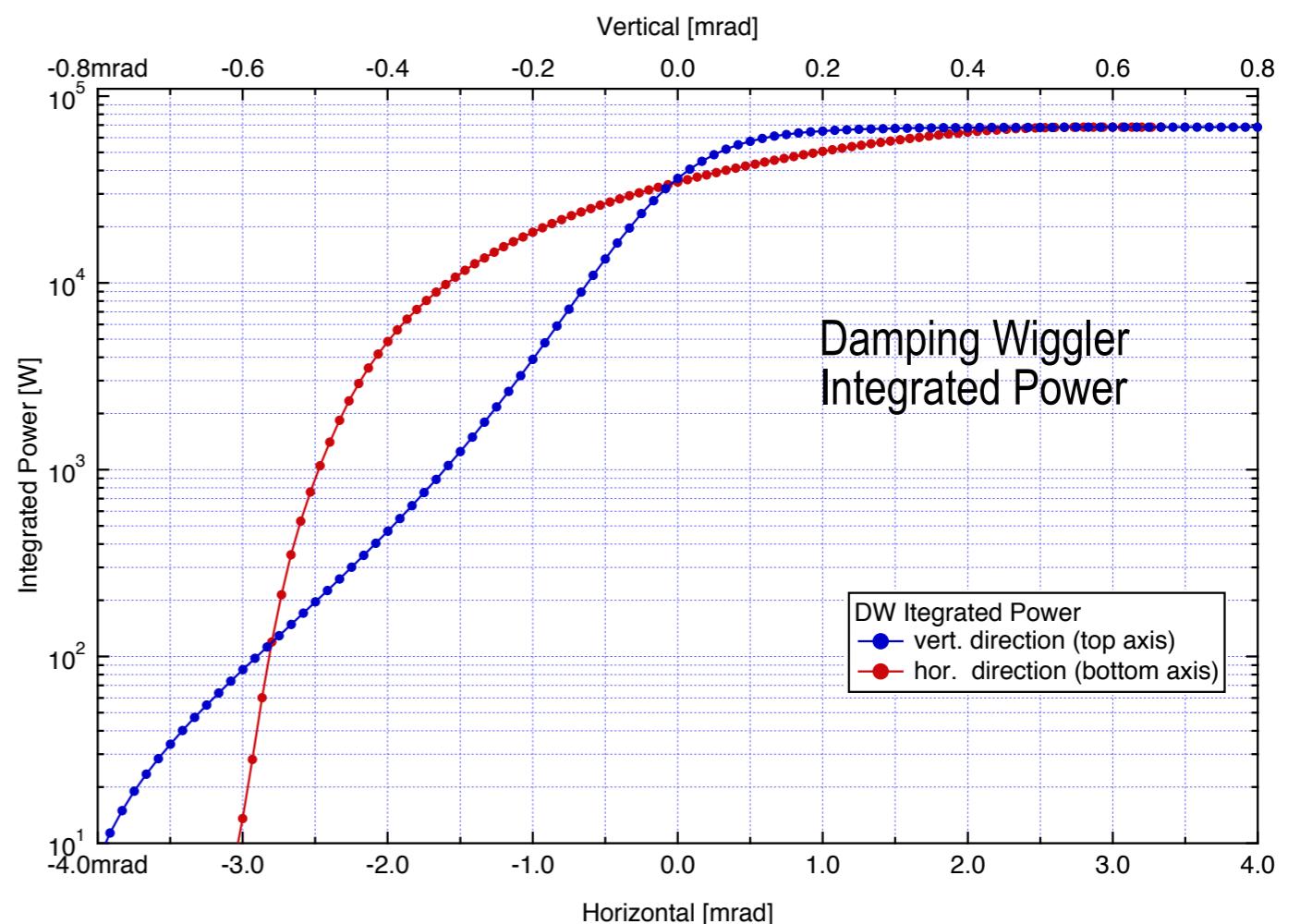
Envelopes



Stay Clear Envelope

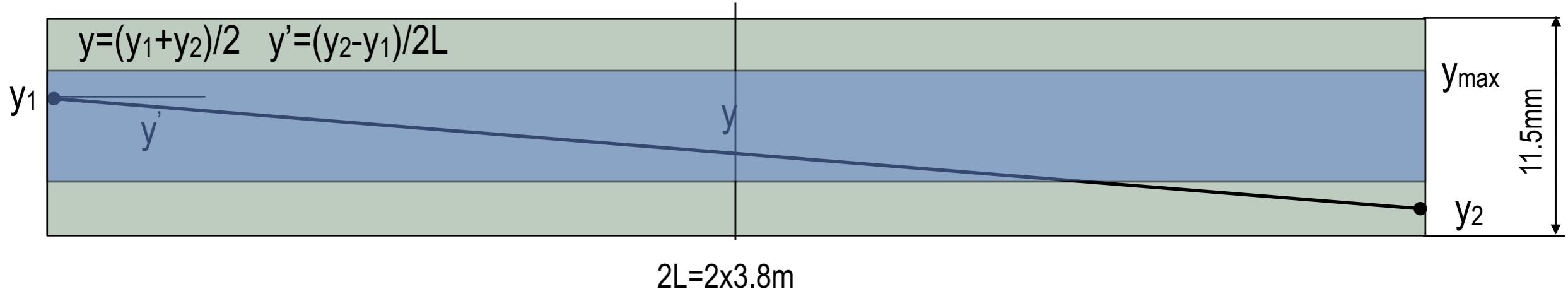


Mechanical Tolerances



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Stay Clear Envelope - BPMs



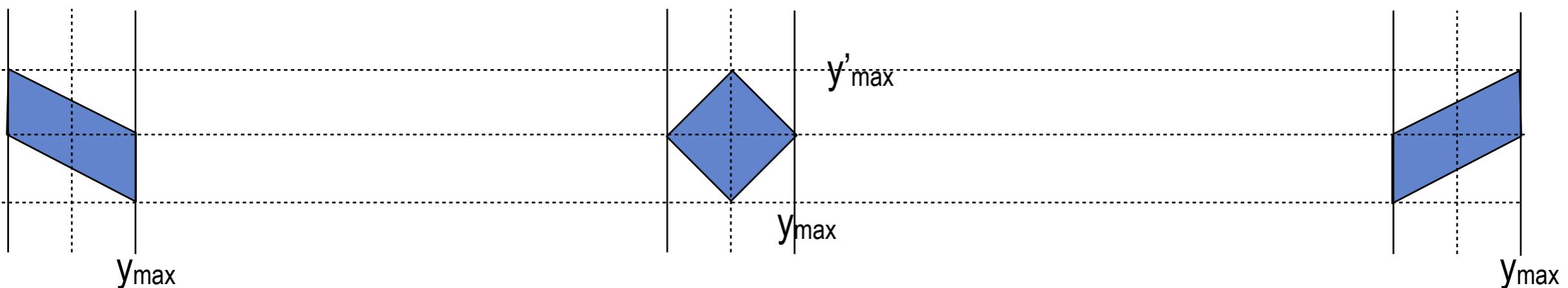
Mechanical Tolerances/Alignment = 1.5mm

Vert. Beam Divergence = $\pm 0.6\text{ mrad}$

DW vacuum chamber:

$$y_{\max} = 5.75\text{mm} - 1.5\text{mm} - 0.6\text{mrad} \times 3.8\text{m} = 1.85\text{ mm}$$

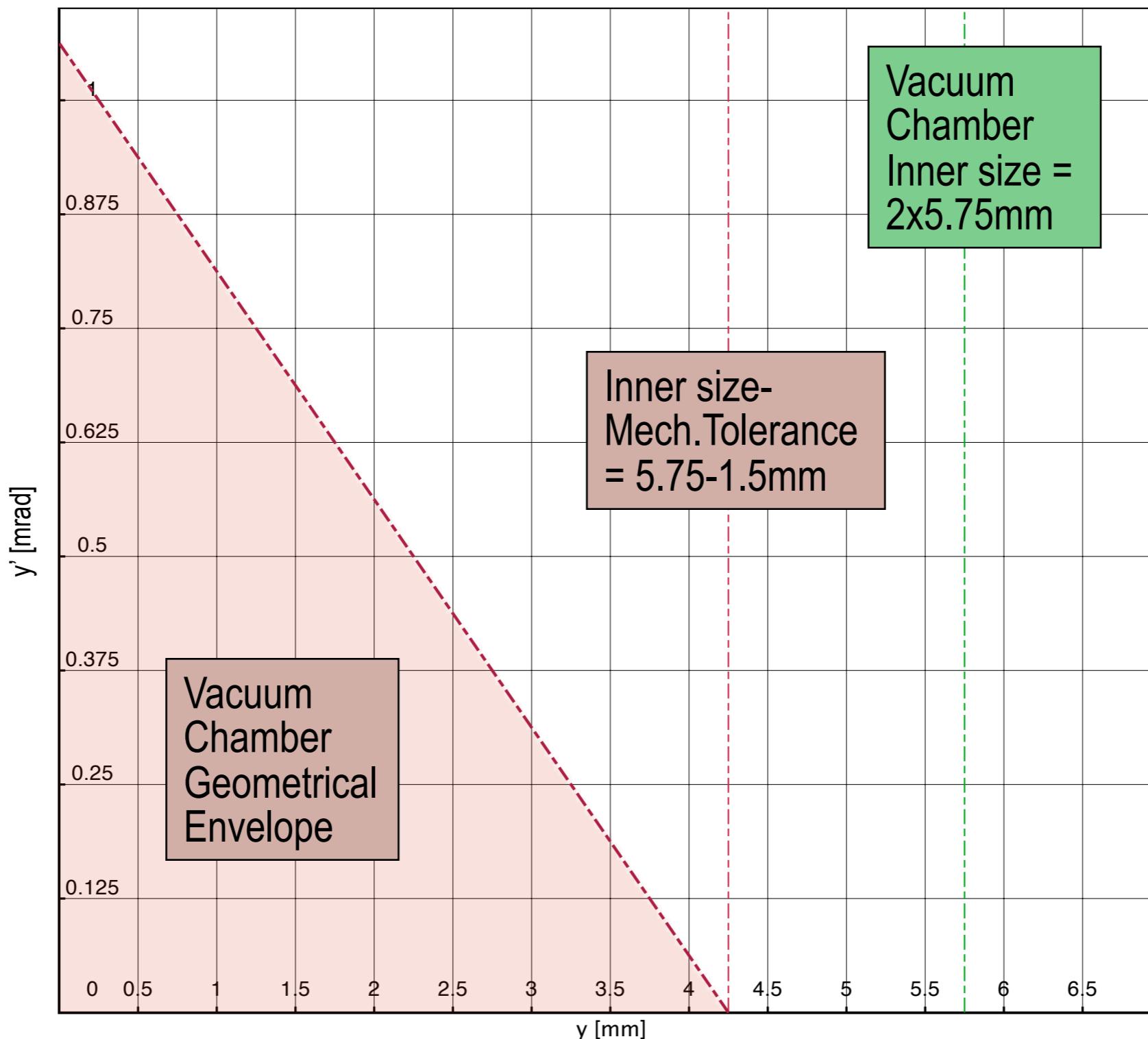
$$y'_{\max} = 1.85\text{ mm} / 3.8\text{m} = 0.49\text{ mrad}$$



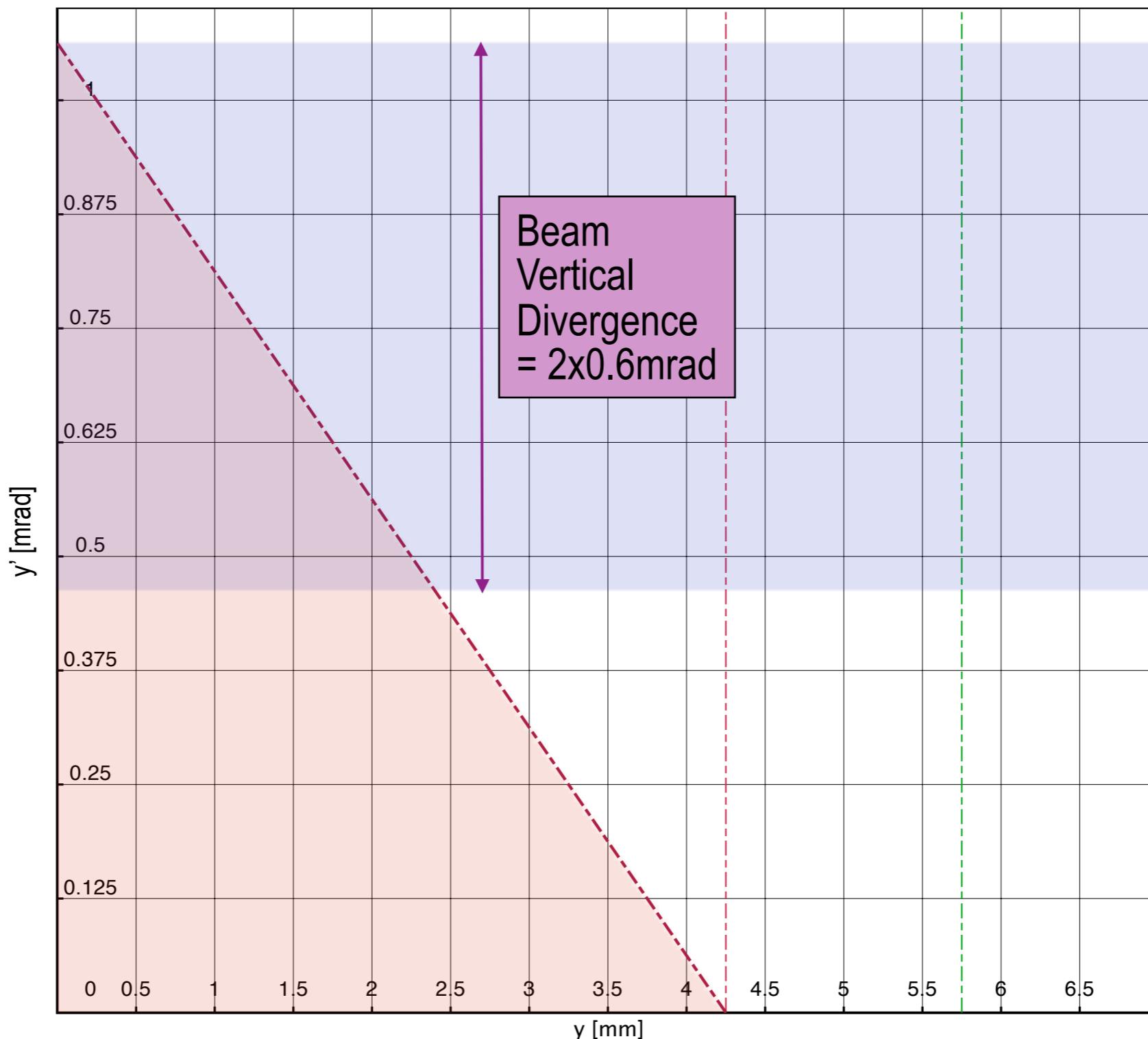
$$|y_1| < y_{\max} \text{ OR } |y_2| < y_{\max}$$



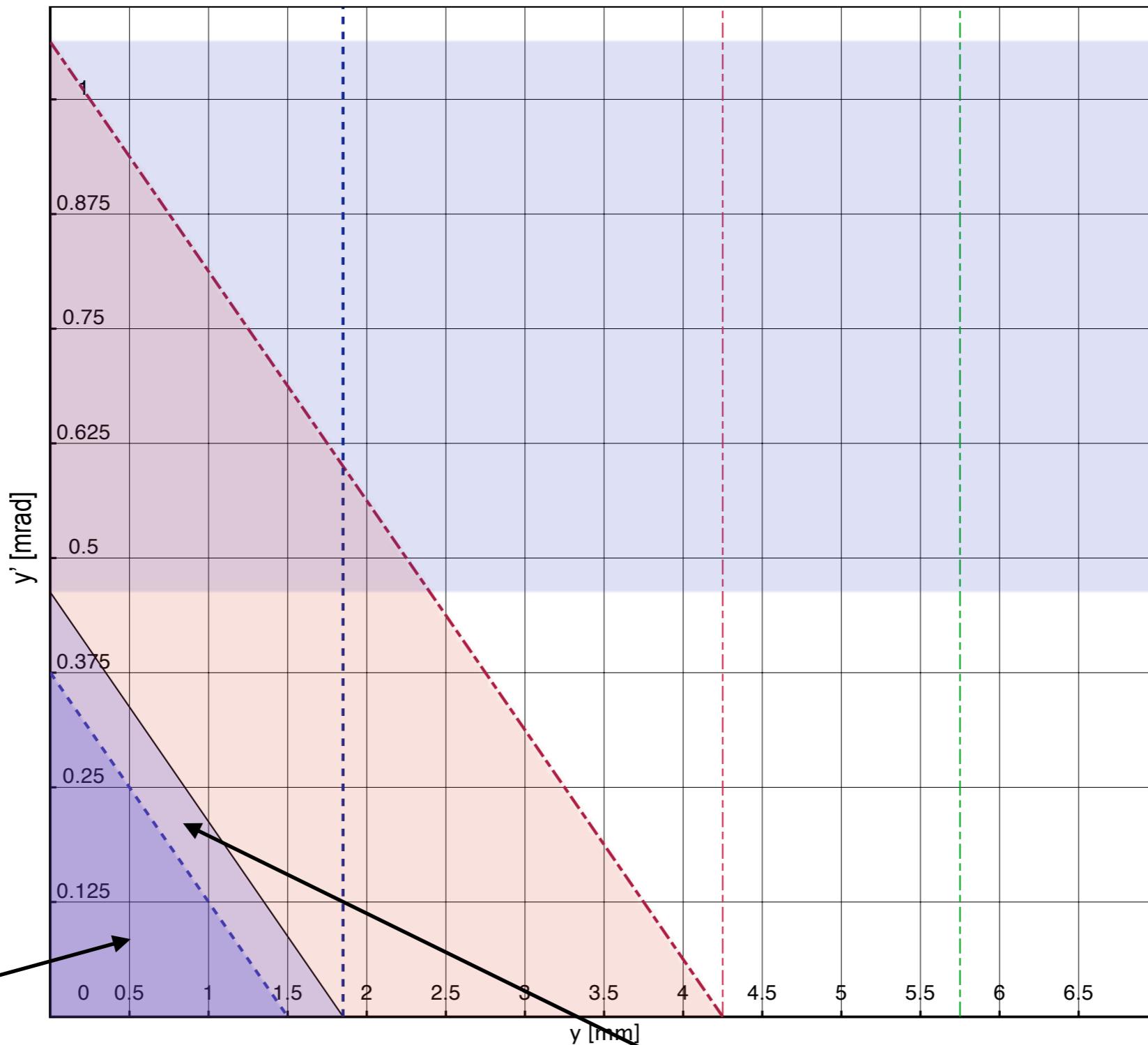
Stay Clear Envelope - DW Vacuum Chamber



Stay Clear Envelope - DW Vacuum Camber



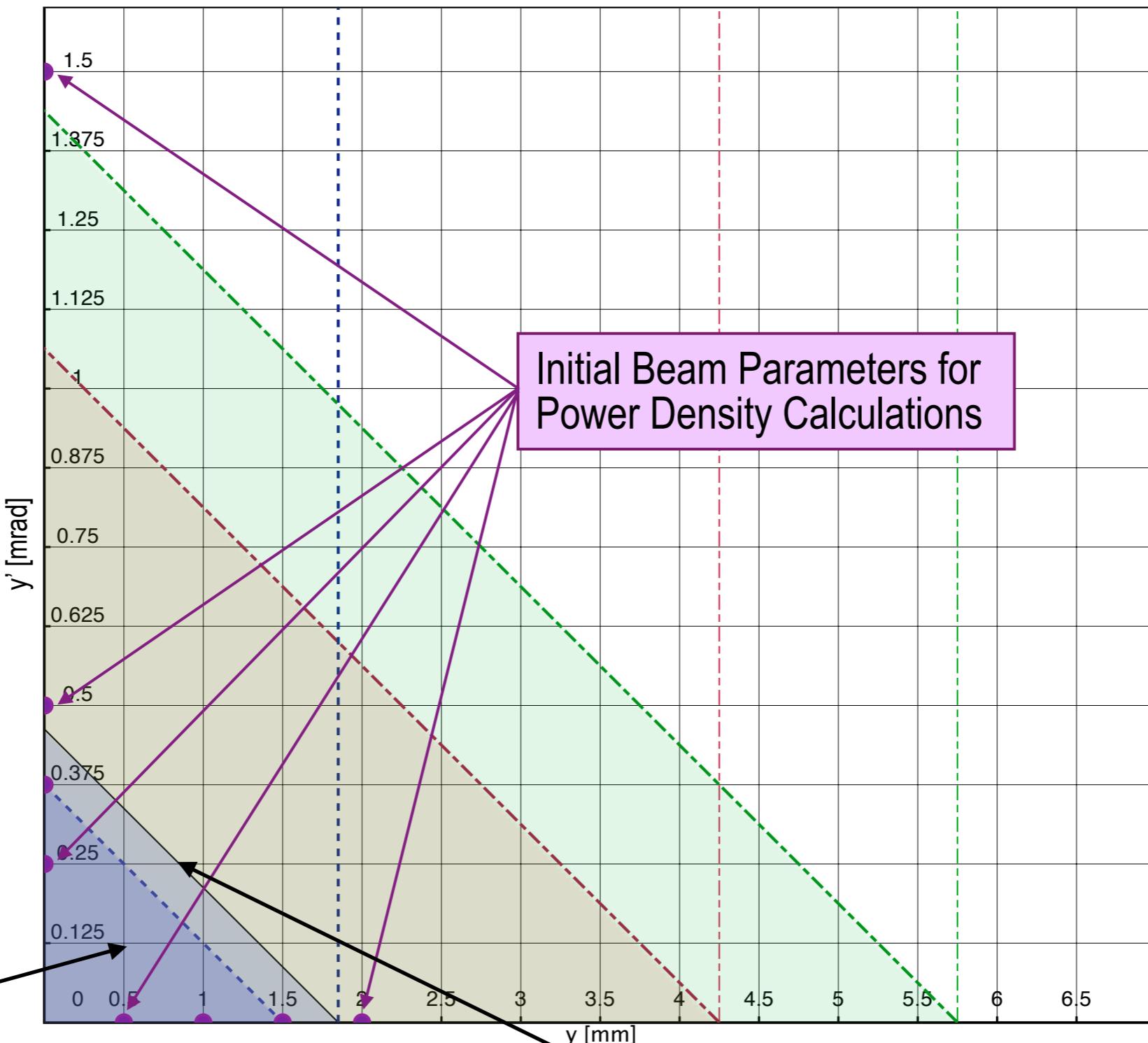
Stay Clear Envelope - DW Vacuum Camber



Active Interlock Envelope - Vacuum Chamber

Stay Clear Envelope - Vacuum Chamber

Power Density - Initial Beam Parameters



Active Interlock Envelope - Vacuum Chamber

Stay Clear Envelope - Vacuum Chamber



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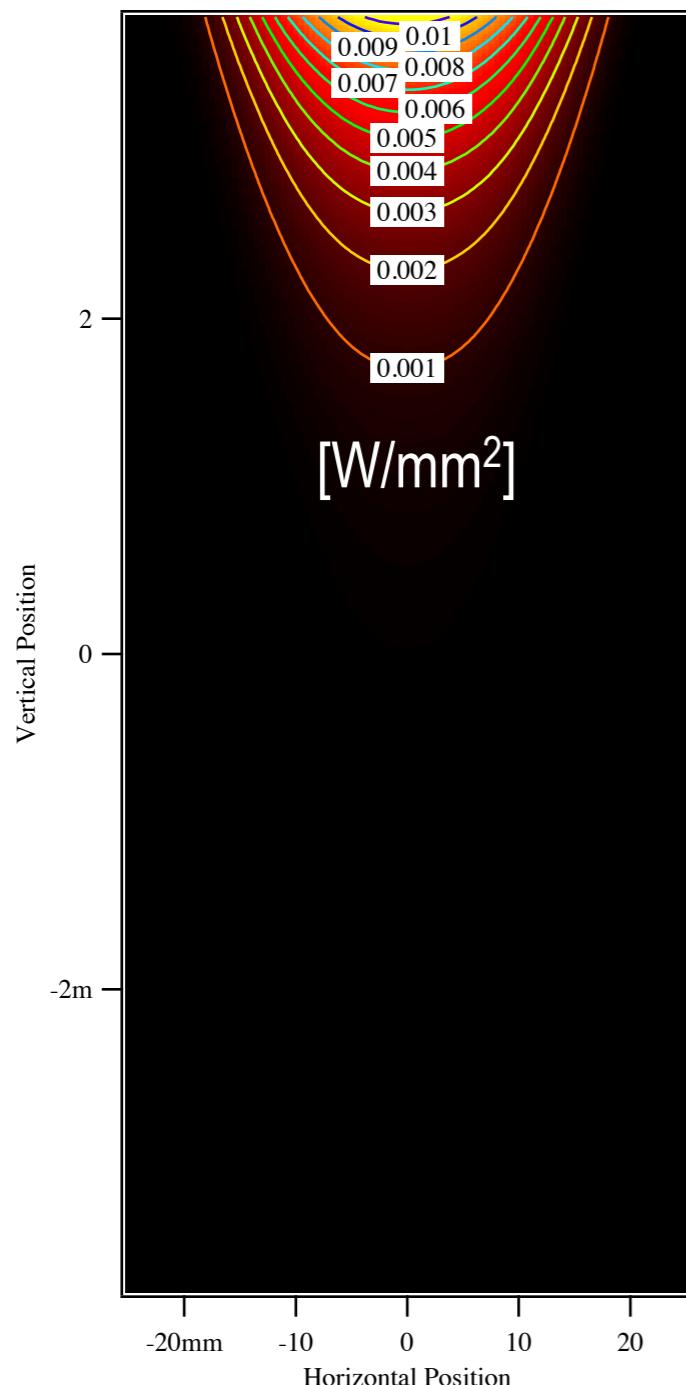
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Steady State Thermal Analyses of Aluminum Chamber

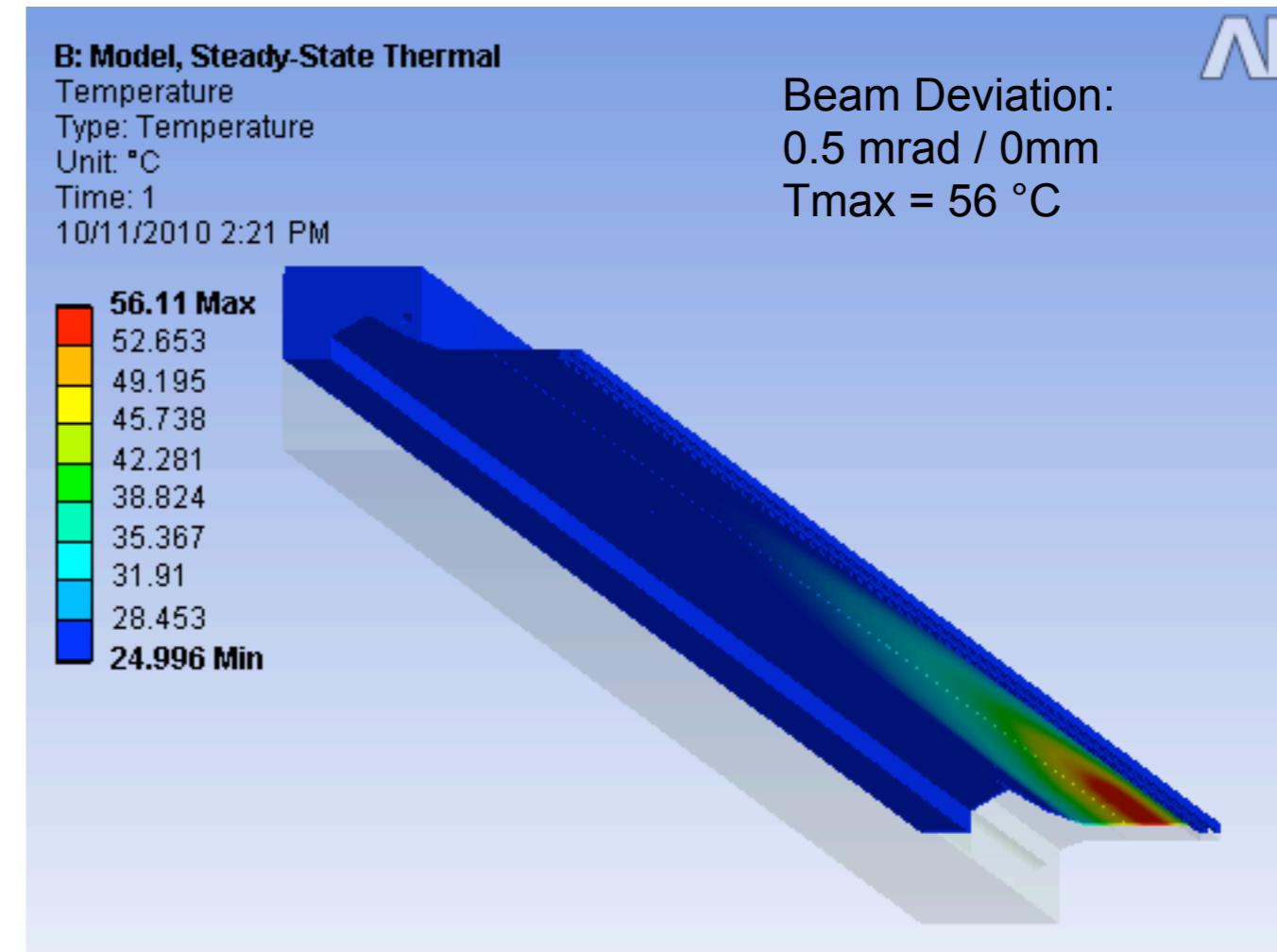
100 mm period Damping Wiggler

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Power Density Distribution



Temperature Distribution



Convection Boundary Conditions:
Water Temperature: 25 °C
Film coefficient: 0.015 $\text{W/mm}^2 \text{ °C}$

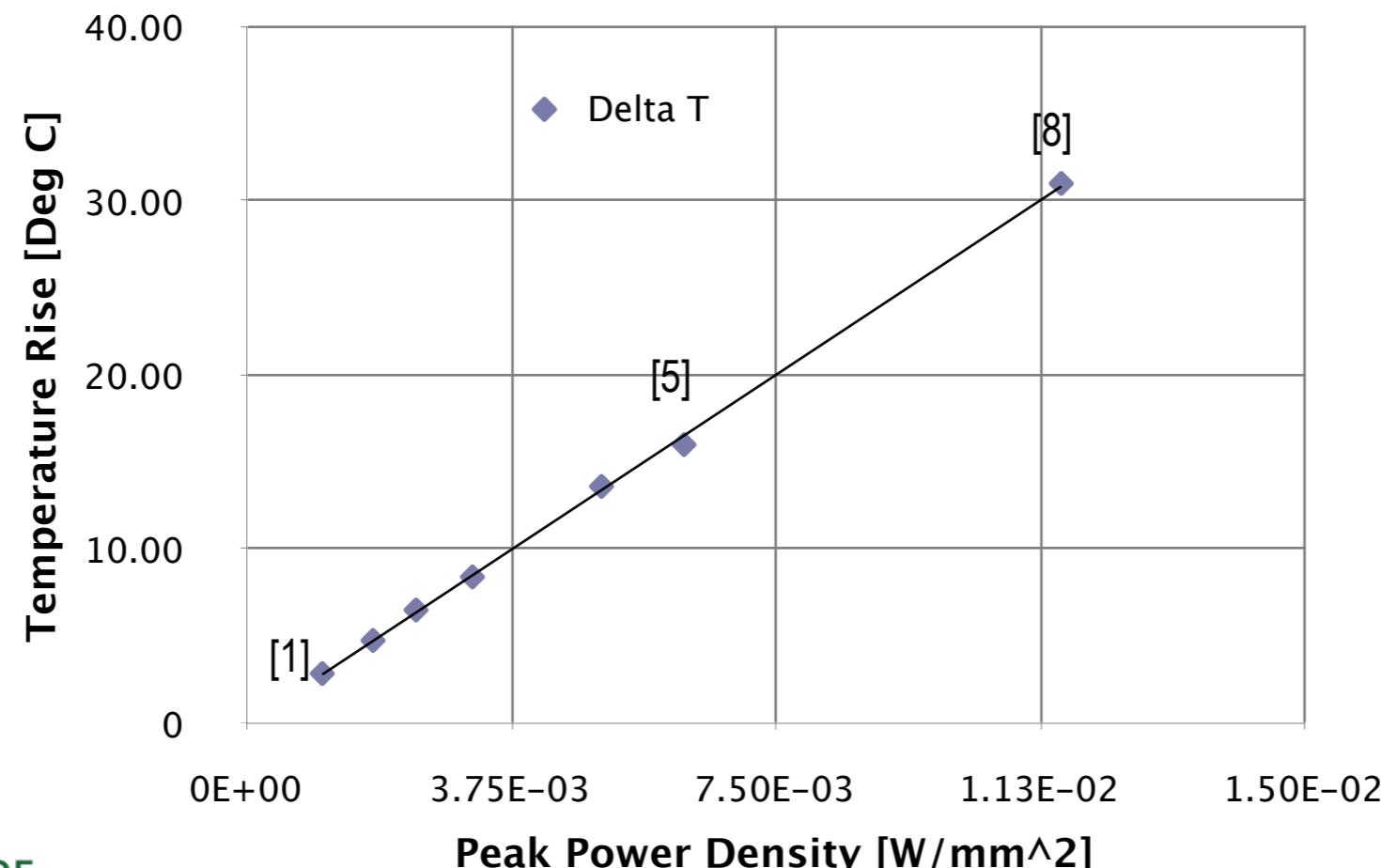


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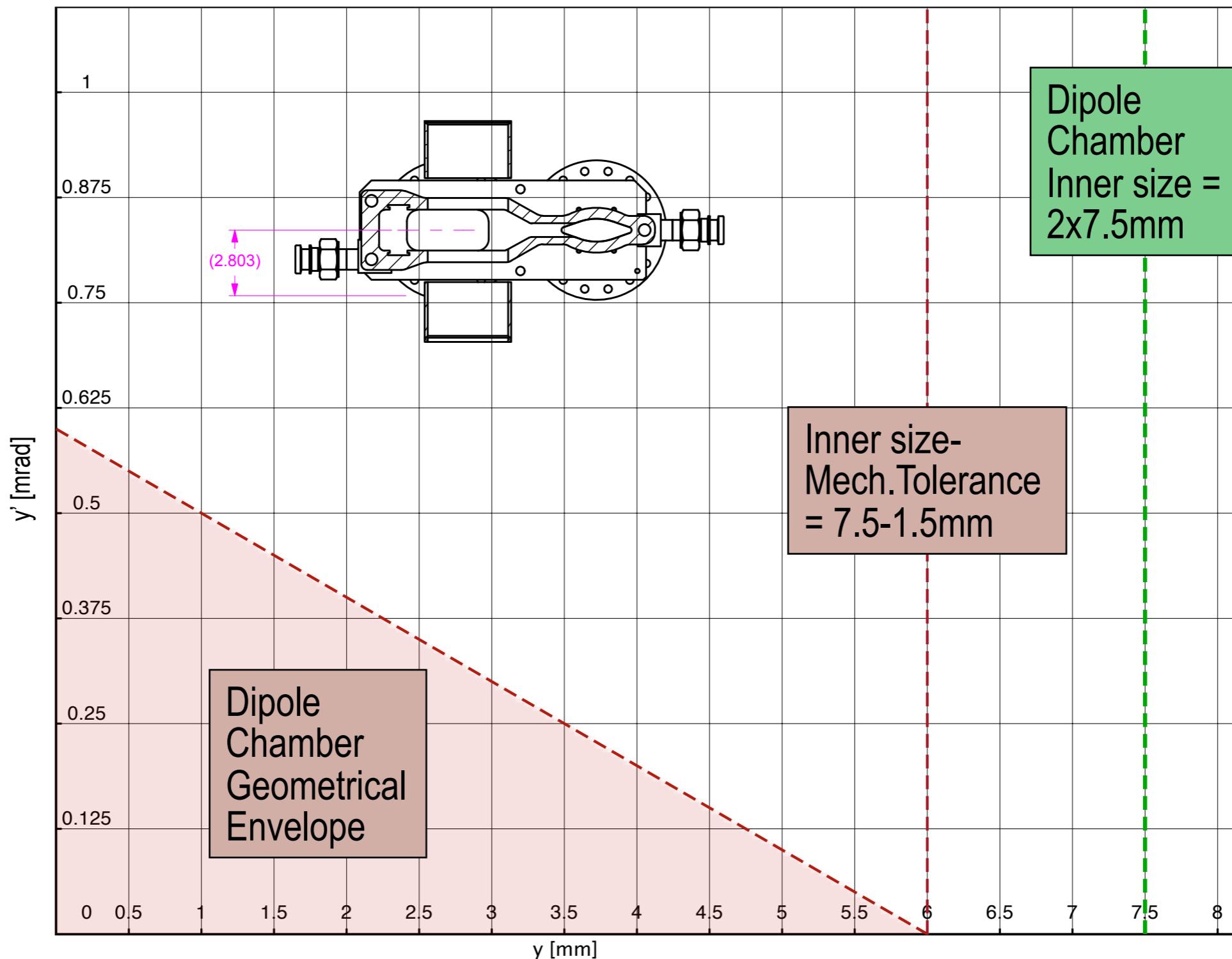
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Temperature Rise - DW vacuum chamber

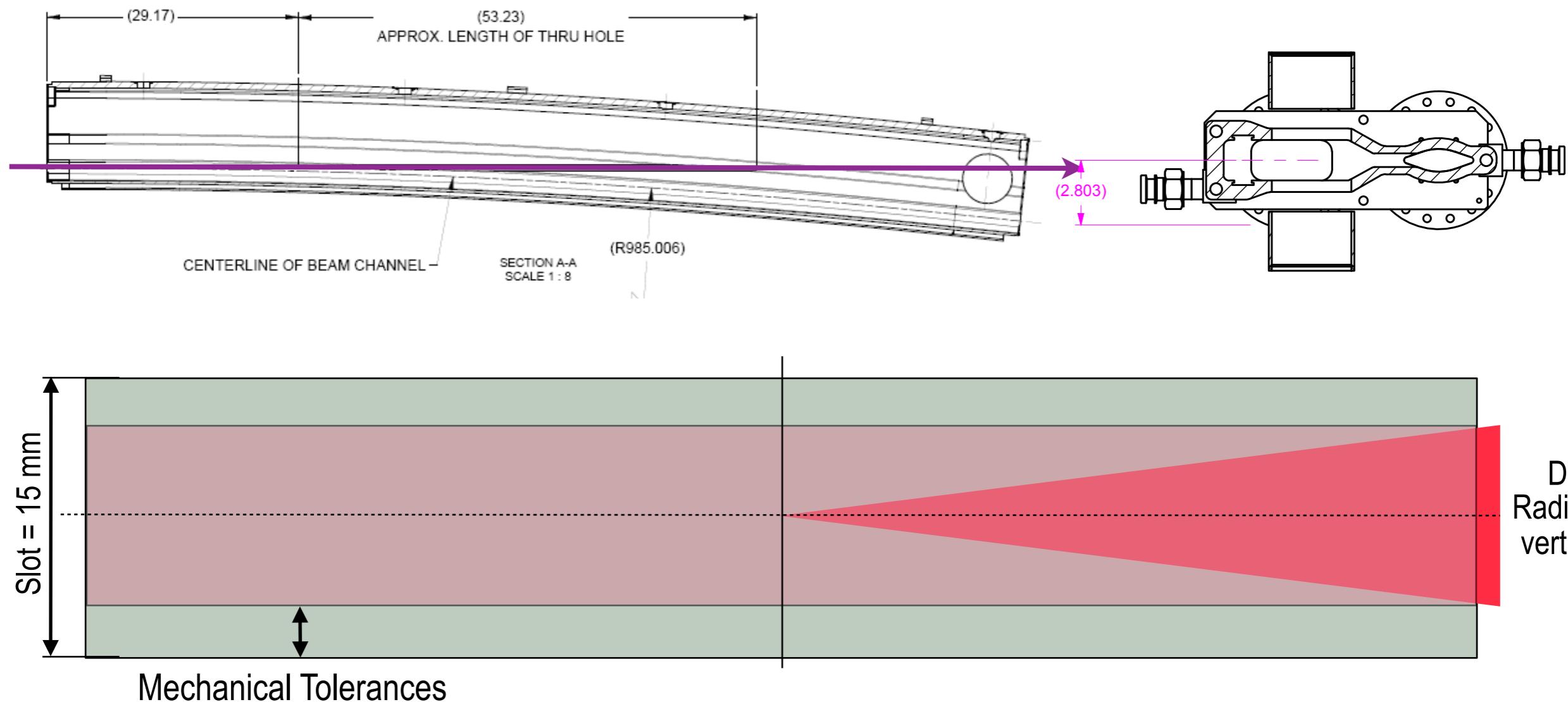
Source	Element	Element Length	Element misalignment [upstr.]	Element misalignment [downstr.]	Case	Beam [Transl]	Beam [Angle]	Peak Temperature	Peak Power Density	Power	
		m	mm	mm		mm	mrad	Deg C	W/mm^2	W	1
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	0.5	0	28	1.1E-03	40	2
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	1	0	30	1.8E-03	68	3
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	1.5	0	33	3.2E-03	124	4
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	2	0	41	6.2E-03	245	5
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	0	0.25	32	2.4E-03	65	6
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	0	0.375	39	5.0E-03	113	7
2xDW100	DW vac. chamber	7.6	-1.5	-1.5	Steady	0	0.5	56	1.2E-02	212	8



Envelope - Dipole Chamber downstream DW



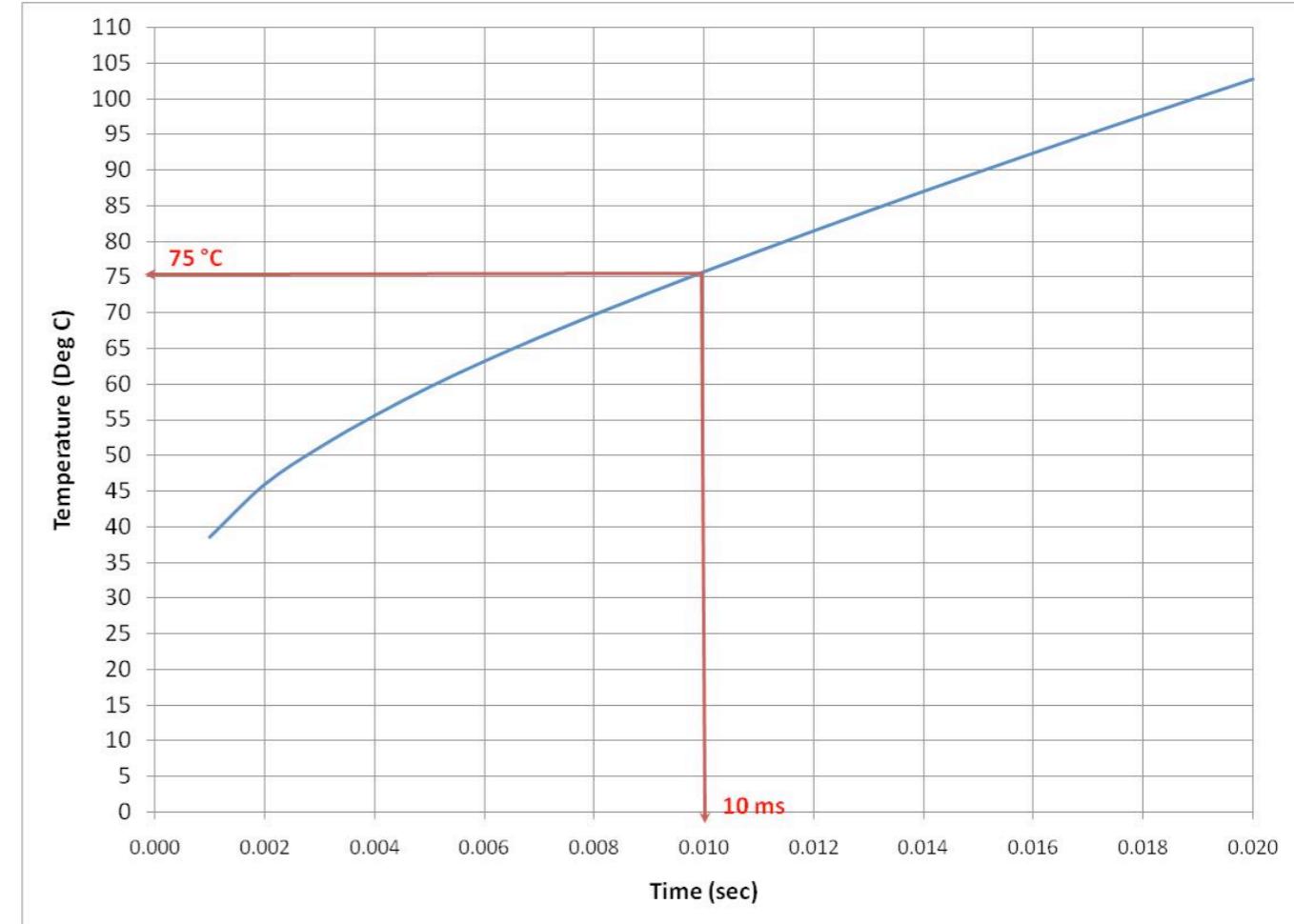
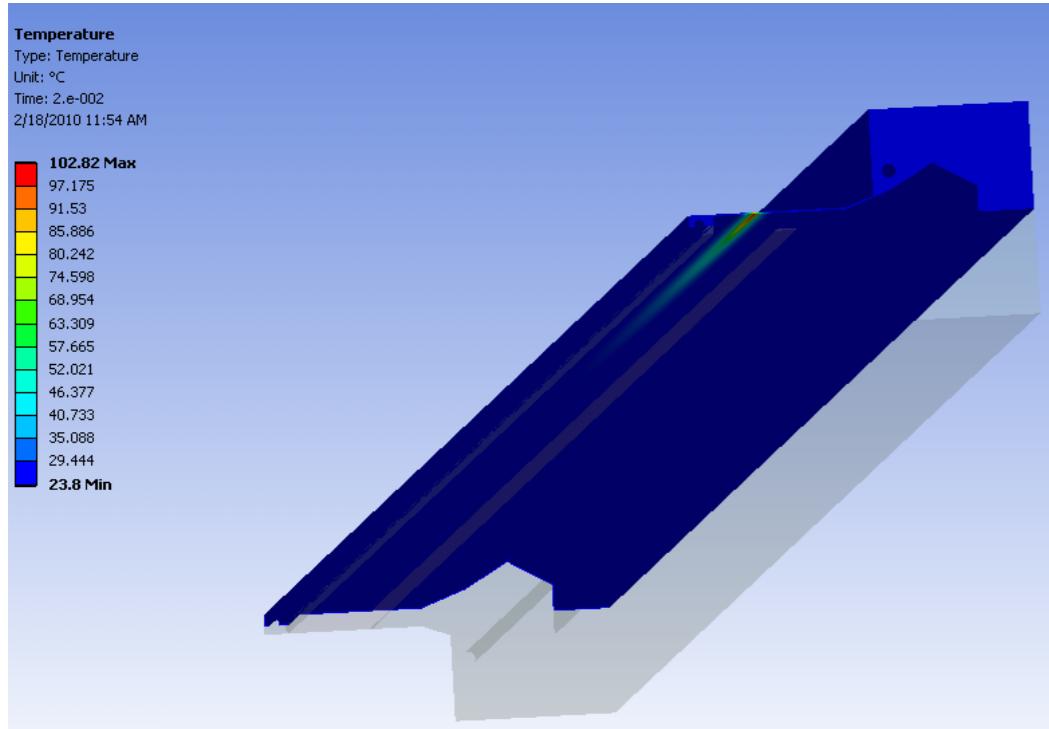
Envelope - Dipole Chamber downstream DW



Stay Clear Envelope cannot be defined, Safe Envelope is defined

Transient Thermal Analyses for 500 mA

100 mm period Damping Wiggler, Beam Deviation: 0.47 mrad /1mm



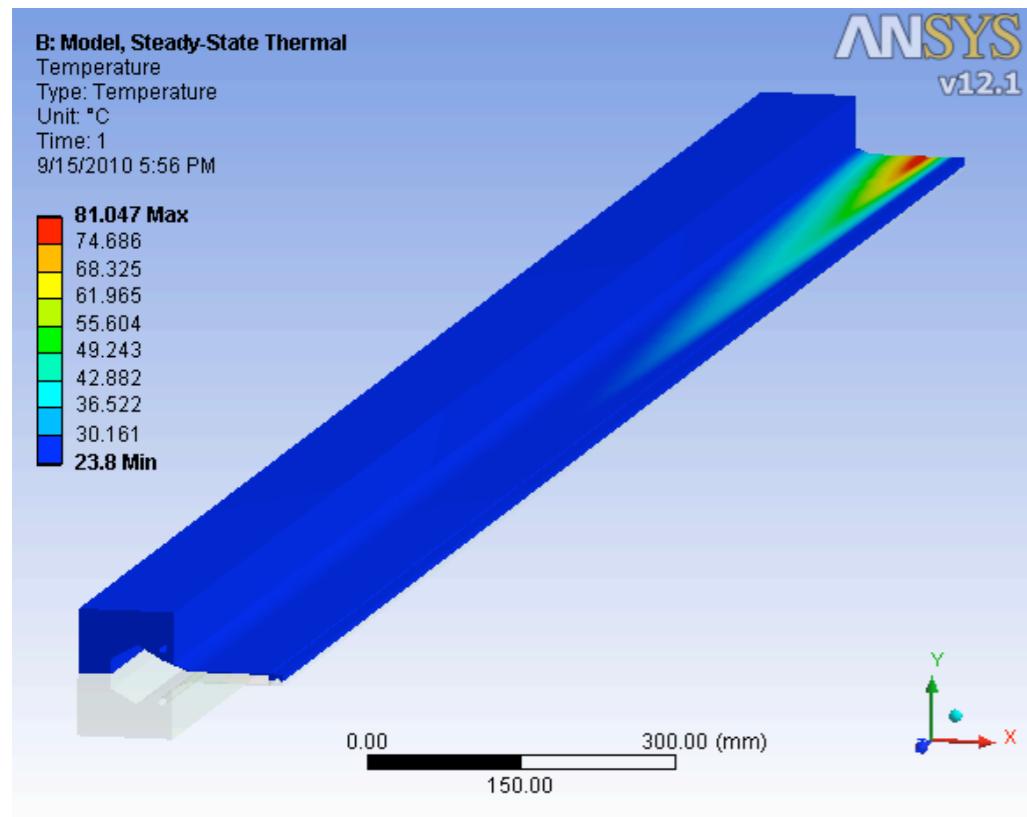
Peak Temperature vs Time

In 20 msec the peak temperature in Aluminum chamber reaches 102 °C

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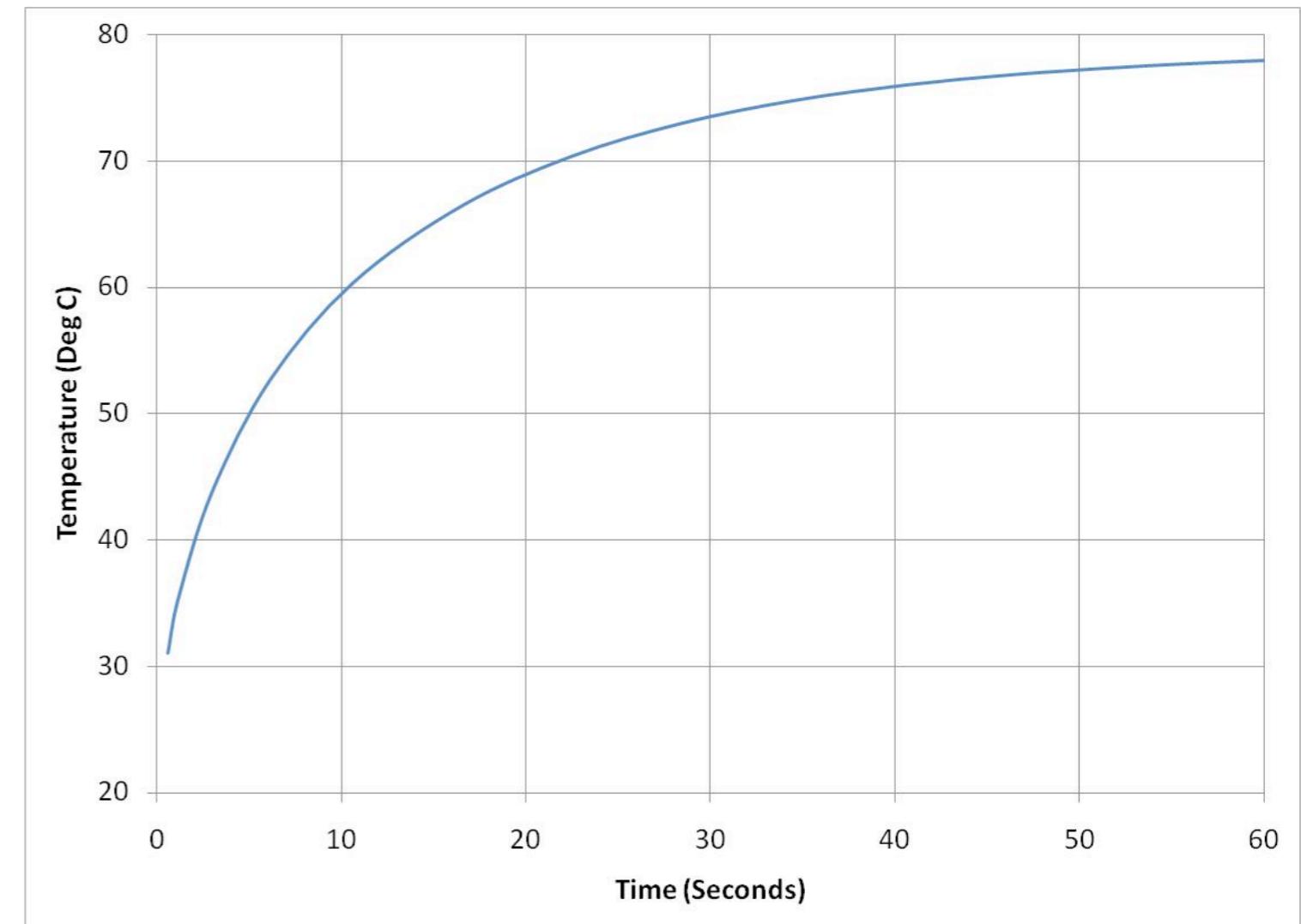
Temperature Saturation at 5 mA

100 mm period Damping Wiggler, Beam Deviation: 0.47 mrad / 1mm



Steady State Temperature distribution

Peak Temperature = 81°C

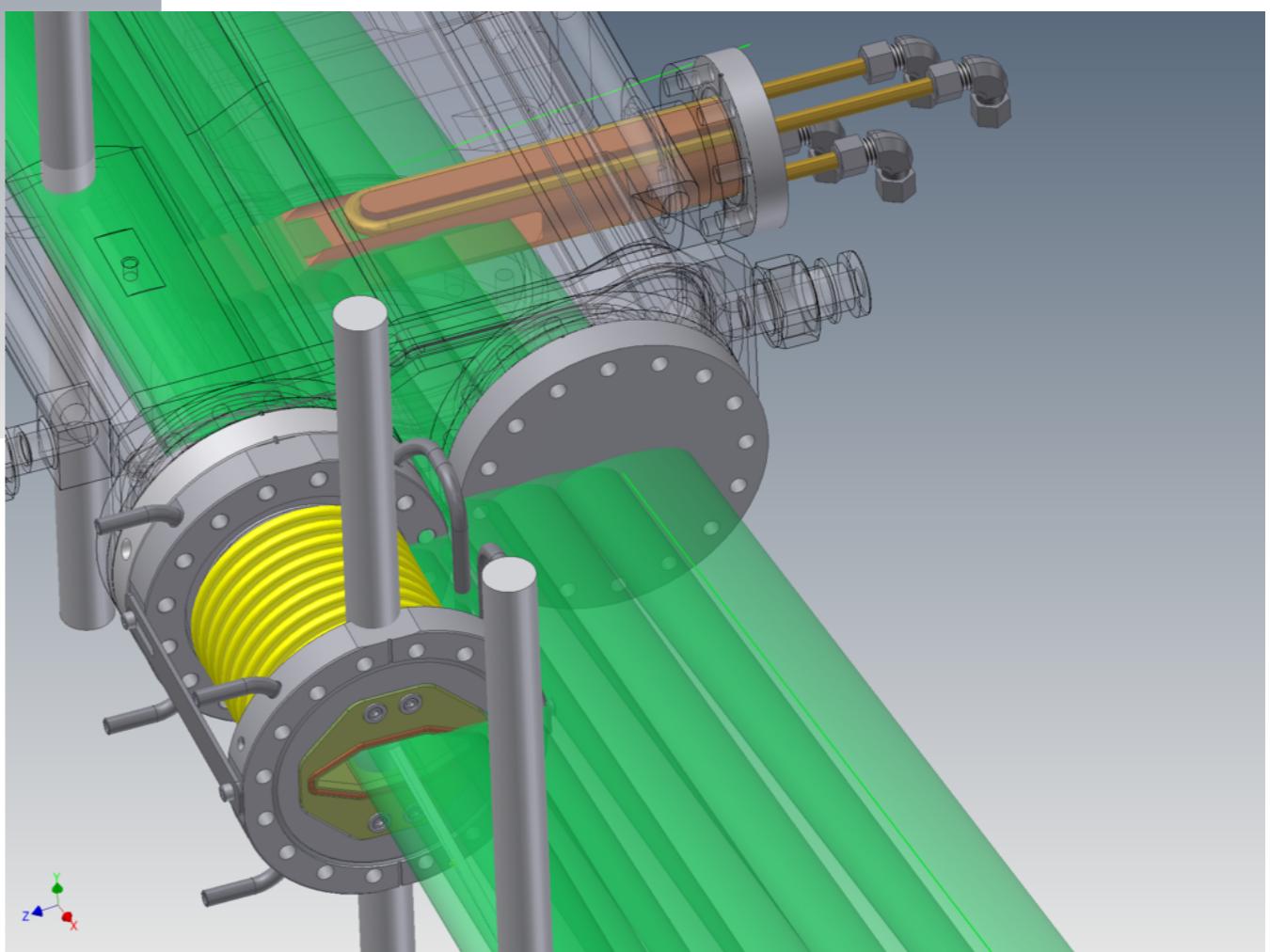
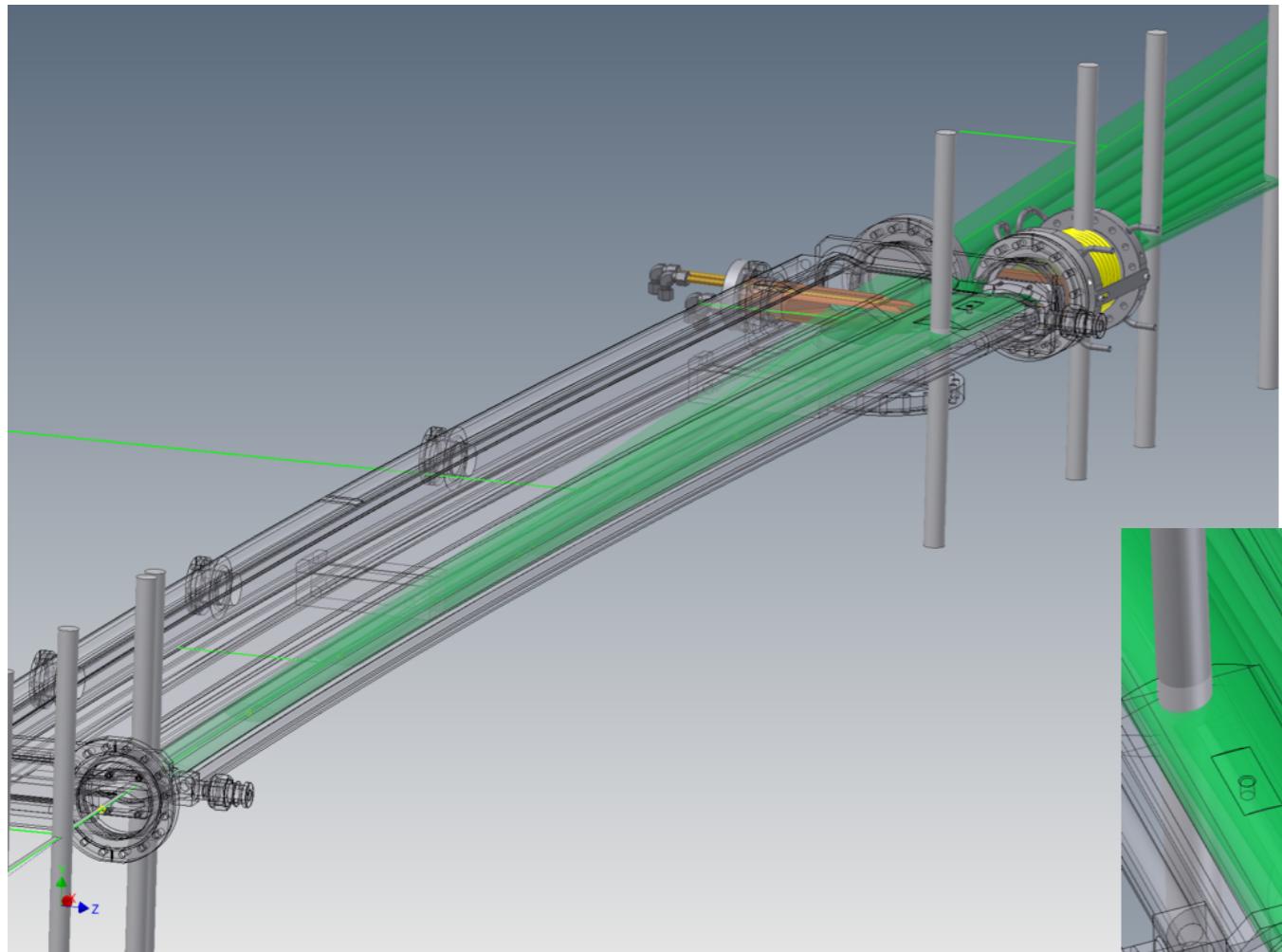


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Passive protection from Dipole Radiation

- **Full Passive Protection**
 - Beam Tracing
 - Geometrical Envelope
 - Beam Envelope
 - Identifying cases
 - beam parameters
 - power density calculations
 - temperature FEA
- **Passive Protection / Safe Envelope**
 - 25 mA
 - 100 mA
 - 500 mA

3D Beam Tracing



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Passive protection for Dipole Radiation - Cases

Source	Element	Element Position [from cent. dip.]	Element Length	Element misalignment [upstr.]	Element misalignment [downstr.]	Element misalignment [transl.]	Element misalignment [angle]	Case	Envelope [Translation]	Envelope [Angle]	Beam Position [vert.]	Beam Position [hor.]	Beam Position [vert. angle]	Beam Position [hor. angle]
		mm	m	mm	mm	mm	mrad		mm	mrad	mm	mm	mrad	mrad
Dipole	S3 end flange adapter							Steady			7< x <7.5	any	any	any
Dipole	S3 crotcher edge							Steady			7	any	any	any
Dipole	S3 crotcher center							Steady			0	any	any	any
Dipole	S3 end block							Steady			any	?	?	?
Dipole	S3 flange absorber							Steady			any	any	any	any
Dipole	S3 RF shielded bellows							Steady			any	?	?	?
Dipole	S3 chamber							Steady			> 7.5	any	any	any
Dipole								Steady			0	0	0	0
Dipole								Steady			0	0	0	0

need to check if **Passive protection for Dipole Radiation** can be achieved for 25, 100, 500 mA storage ring currents

Thank You !